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The Main Drivers of Biodiversity Loss: A Brief Overview

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Abstract

This paper provides a comprehensive exploration of the primary drivers leading to global biodiversity loss based on recent scientific research. These drivers are agricultural expansion, climate change, marine exploitation, urbanization and the spread of invasive species. The paper examines the significant role of land use change, responsible for endangering 85% of species at risk, largely through habitat transformation. The impacts of climate change on ecosystems are discussed, including ocean warming, acidification, and altered ocean currents; factors that pose challenges for various species. Marine exploitation contributes to the decline of marine species and habitats. The paper also discusses how urbanization leads to habitat fragmentation, and the threats posed by invasive species that disrupt native ecological networks. Assessing the drivers of biodiversity loss creates a knowledge baseline for action.

Keywords: Agricultural Expansion; Climate Change; Marine Exploitation; Urbanization

Introduction

The threat of biodiversity loss on a global scale poses challenges for the resilience of marine and land based ecosystems, with the potential to affect the underlying economy and our human life and health. To remediate the problem, policy-makers and investors need a thorough understanding of the drivers that cause biodiversity loss.

In the Global Assessment Report on Biodiversity and Ecosystem Services from 2019, IPBES stated that biodiversity loss is driven by changes in land and sea use, direct exploitation of organisms, climate change, pollution, and invasion of alien species. Starting with the foremost contributor, land-use change, particularly deforestation for agriculture, agricultural expansion is responsible for putting 85% of species at risk.

Research Questions and Methodology

The paper answers the following research question: What are the main drivers of biodiversity loss?

The research methodology used mainly consists of a literature review, surveying recent scientific studies in the fields of biodiversity loss, conservation biology, ecology, etc. This systematic approach involves the critical reading of existing research papers, reports, and articles. By using content analysis, the literature review identifies themes and trends to map the current state of knowledge on biodiversity loss.

Various Sub Definitions of Biodiversity and Biodiversity Loss

Biodiversity, or biological diversity, as defined by the United Nations Convention on Biological Diversity, is "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." (CBD, art.2)

Biodiversity loss can be regarded as the reduction or loss of biological diversity at the genetic, species, or ecosystem level. Understanding biodiversity loss means mapping how these levels of biological complexity interact and co-depend.

Genetic Diversity

At the most fundamental level, genetic diversity is the variation of genes within a species, and contributes to variation within populations, allowing them to better adapt to changing environmental or climatic conditions. A loss of genetic diversity weakens the population's resilience. Lower resilience to diseases could make extinction more likely. This loss can be observed when habitat fragmentation restricts gene flow, leading to inbreeding. Conservation efforts that promote genetic diversity, such as natural corridors for wildlife movement or conserving diverse seed banks for plant species, can ensure better adaptability.

Understanding and preserving genetic diversity is thus an essential aspect of biodiversity conservation, playing a critical role in the survival and long-term viability of species [1].

Species Diversity

Species diversity includes the number and variety of species in a particular region. Losing species can disrupt ecosystems, leading to unforeseen consequences. The extinction of a predator or a pollinator can have knock-on or cascading effects on the entire food web. Occasionally, the loss of a keystone species may destabilize an ecosystem due to its critical ecological role, or a decline of plant species can influence herbivore or insect populations that rely on the plant as an essential food resource. The introduction of alien species can outcompete native species, if they develop into invasive species altering ecosystem structure. Such alterations in species diversity can lead to changes in ecosystem functions and resilience, affecting both local and global ecological balance [2].

Ecosystem Diversity

At the largest scale, ecosystem diversity refers to the variety of different ecosystems present on the planet. Examples of this diversity include tropical rainforests, characterized by dense tree cover and high rainfall; coral reefs, which are complex underwater ecosystems with diverse marine organisms; grasslands, consisting of open areas populated by various grass species and grazing animals; and the tundra biome, marked by cold summer climates and an absence of trees.

Other examples encompass wetlands, including marshes and swamps, rich in aquatic plant life; deserts, defined by arid conditions and sparse, drought-resistant flora; temperate forests, with seasonal changes affecting a predominance of broad-leaved trees; and taigas, which are coniferous forests known for cold winters and a variety of large mammal species.

Additionally, savannas, combining grasslands with scattered trees, and mountain ecosystems, characterized by rugged terrain and steep habitat gradients, contribute to the broad spectrum of ecological diversity. Each ecosystem has a unique assortment of species that interact with each other and their environment in complex ways. Loss of ecosystem diversity could lead to the disappearance of unique habitats and the specialized species that live there [3].

Land-Use Change

The IPBES Global Assessment Report on Biodiversity and Ecosystem Services highlights the main drivers of ecological degradation, primarily the human transformation of land and sea ecosystems [4]. From 1990 to now, this change has caused the loss of roughly 420 million hectares of forests, turning them into agricultural lands and urban zones. Agricultural sprawl is central to deforestation, leading to both the degradation of forests and loss of biodiversity. Globally, the food system is particularly damaging; research indicates that 85% of the 28,000 species nearing extinction are threatened by agriculture (Iisd.org).

The growing world's population fuels the drive for more intense farming practices, resulting in widespread habitat destruction and biodiversity loss. Several scientific articles support the statement that agricultural expansion is a significant driver of species at risk: Tilman [2] highlights the impact of intensive agriculture on the environment and biodiversity, and suggests that sustainable agriculture practices are necessary to mitigate these impacts. Ramankutty [5] discusses the effects of land use change on ecosystems and biodiversity, and highlights the importance of restoring degraded and unused farmland to protect and restore crucial ecosystems such as forests, peatlands, and wetlands. Newbold [6] conducted a global assessment of the impact of land use on biodiversity and found that agriculture was the primary driver of terrestrial biodiversity loss. The study estimated that agriculture was responsible for over 80% of the global terrestrial biosphere's transformation and habitat destruction, leading to the loss of many species.

Also, Ripple [7] states that the expansion of agriculture is one of the primary drivers of species loss and the loss of natural ecosystems, and calls for transformative changes in agriculture and other sectors to protect biodiversity and mitigate the climate crisis.

Insecticides

Among the factors contributing to biodiversity loss and ecosystem alterations, pollution—particularly the presence of chemical contaminants and waste—ranks highly. One of examples of this effect is the use of broad-spectrum insecticides with high toxicity levels. The unchecked use of such substances leads to a decline in both plant and insect populations, disrupting the balance of ecosystems. This has been covered by [8].

Neonicotinoids are widely used insecticides known for their effectiveness. However, their large-scale and preventive use is raising concerns about their impact on the environment, particularly on insects. Studies have shown that these insecticides can harm non-target organisms, leading to a decline in biodiversity and affecting food production. The decline in honey bee colonies is a notable example, with evidence linking it to neonicotinoid use. The global research landscape is increasingly focusing on neonicotinoids and the ecological issues surrounding this insecticide, with a significant rise in publications and interest in the subject. Ensuring more sustainable food production depends on finding solutions to the challenge posed by neonicotinoids. This will require a global approach, including greater involvement from developing countries, to preserve insect biodiversity [9].

Another specific example is the pesticide-driven degradation of aquatic environments, with particular emphasis on Australia's Great Barrier Reef. Both general pesticides and specific insecticides contribute to this degradation. Aquatic biodiversity is influenced by pesticides, and the paper underscores the pressing need for refined pesticide and insecticide management strategies to curtail the adverse effects on aquatic habitats and their biodiversity [10].

Marine Plastic Pollution and Microplastics

Marine pollution from plastics is a growing concern, leading to fatalities in 80 species like cetaceans, sea birds, and sea turtles. Specific items such as flexible plastics, ropes, and fishing nets are often lethal, causing gastric obstructions and other issues.

Surprisingly, smaller "microplastics," despite their abundance, are seldom implicated in mortality. The study identifies key consumer items responsible for most megafauna deaths and proposes targeted policies to reduce or eliminate these particularly hazardous items in marine environments. The complexity of the problem might seem overwhelming, but prioritizing interventions on these key sources of pollution can create meaningful change in reducing mortality among marine megafauna [11].

Nitrogen and Eutrophication

Simultaneously, with the exacerbation of global environmental challenges, there has been an uptick in air and soil pollution, characterized by an alarming increase in atmospheric nitrogen deposition.

This phenomenon contributes substantially to a decrease in biodiversity through the process of eutrophication, which involves an overabundance of nutrients, particularly nitrogen compounds. These compounds lead to excessive algal growth in aquatic ecosystems, subsequently reducing marine oxygen levels.

The nitrogen responsible for this process primarily originates from agricultural runoff and industrial emissions, becoming part of a complex nexus of environmental issues. Excessive nitrogen in soil can cause acidification, impacting plant growth, food chains, and even the quality of agricultural products.

A 2014 study examined 41 grasslands, finding that greater species diversity led to a stable biomass production, but chronic fertilization and eutrophication weakened the productivity. The findings emphasize the complex interactions between diversity, eutrophication, and stability in ecosystems [12].

The broader implications of nitrogen deposition necessitate coordinated global action. This issue extends beyond ecological concerns, affecting communities that rely on fishing and agriculture. Comprehensive strategies must be employed to monitor, control, and mitigate nitrogen deposition to preserve biodiversity, ensuring the health of aquatic and terrestrial ecosystems, and safeguarding the wellbeing of future generations within the context of a sustainable environment.

Harvesting Materials from Oceans

In addition to agriculture, other human activities such as harvesting materials from the ocean floor can have detrimental effects. The exploitation of ocean resources can lead to the destruction of marine habitats, leading to habitat loss, which can result in the displacement or extinction of many species. The extraction of resources from oceans is a significant driver of biodiversity loss, with several associated mechanisms contributing to this ecological degradation.

Overfishing, the harvesting of marine species at unsustainable rates, leads to drastically reduced fish populations and possible extinction of targeted species. This imbalance can trigger a domino effect on the entire marine ecosystem due to the interconnected nature of its species. Bycatch, the unintentional capture of non-target species like sea turtles and dolphins, further contributes to population declines and affects marine biodiversity. Additionally, destructive practices such as bottom trawling damage vital habitats like coral reefs and seagrass beds, leading to declines in both the quantity and diversity of marine life. [13] analyzed global trends in marine fish populations and fishing practices in an article in Science in 2009, and found that overfishing has led to a decline in the abundance of many marine fish populations, and that implementing sustainable fishing practices was critical for rebuilding depleted fish populations and maintaining healthy marine ecosystems.

Exactly how human activities have influenced biodiversity loss in the world's oceans has been subject of several articles. One study found that fishing and other extractive activities have had significant negative impacts on marine ecosystems, including decline in biodiversity and ecosystem services. Overfishing, bycatch, habitat destruction, and climate change are leading to declines in marine biodiversity and ecosystem health. [14] found that the effects of these activities are increasing over time and that urgent action is needed to address the cumulative impacts of human activities on the oceans.

Climate Change

Climate change contributes significantly to biodiversity loss. Three primary aspects of climate change impact marine ecosystems: increasing ocean temperatures, rising ocean acidity, and alterations in ocean currents.

Rising Ocean Temperatures

As atmospheric temperatures rise due to increasing greenhouse gas emissions, ocean temperatures follow suit. Warmer oceanic waters can lead to the bleaching of coral reefs, an event in which the symbiotic algae that provide corals with food are expelled, leading to coral death if the bleaching is prolonged. Additionally, many marine species are sensitive to changes in temperature and may struggle to survive if their habitats become too warm.

A pronounced effect of ocean warming is the displacement of species and ecosystems towards the poles. Since available sea and terrestrial area decreases towards the poles, this means reduced habitat envelopes, culminating with Arctic squeeze close to the North Pole. At both poles, heavily reduced sea ice thickness and extent is a threat to several ice-adapted marine mammals, seabirds and other biota [15].

Increasing Ocean Acidity

As the level of atmospheric carbon dioxide rises, more is absorbed by the world's oceans. This results in ocean acidification, a process that can have damaging effects on marine life, particularly species with calcium carbonate shells or skeletons, such as mollusks and corals. The increased acidity can reduce the capacity of these organisms to build and maintain their structures, leading to population declines and disruptions to the broader ecosystem.

Altered Ocean Currents

Climate change can also disrupt ocean currents, which are essential for distributing heat, maintaining regional climates, and supporting marine food webs. One concerning example is the potential weakening or collapse of the Atlantic Meridional Overturning Circulation (AMOC). The collapse of the AMOC has been a topic of particular interest from researchers due to a weakening trend, causing scientists to warn about a potential slow-down and collapse mid-century, earlier than previous IPCC predictions [16].

A collapse of the AMOC would be a high impact-low probability event with significant impact on biodiversity for several reasons: Changes would influence weather systems, rainfall and nutrient availability, which in turn affects primary production and the broader marine food web, potentially leading to significant changes in biodiversity over a short period of time, making it difficult for species to adapt to local climate change.

Desertification

Rising temperatures and altered precipitation patterns can lead to the degradation of fertile lands, turning them into arid, non-productive regions, and spreading desertification. This transformation results in the loss of plant species adapted to more temperate conditions. Consequently, animals dependent on these plants may go extinct, driving biodiversity loss. Desertification also diminishes the land's capacity to support agriculture, further stressing the ecosystem [17].

Water Shortages

Climate change also affects water availability, leading to water shortages in many regions. Reduced rainfall and increased evaporation rates can cause rivers, lakes, and other wetlands to dry up, impacting the numerous species that rely on these freshwater habitats. The alteration or loss of these ecosystems can have cascading effects on food webs and lead to declines in both aquatic and terrestrial biodiversity [18].

Invasive Species

Invasive species, defined as non-indigenous or non-native organisms introduced to new ecosystems, stand as a major driver of biodiversity loss. These species are often transported into new environments by humans through deliberate introduction, international trade, tourism, and notably, carried in the ballast water used by container ships.

Ballast water, used to stabilize ships during transport, often inadvertently contains various species that can be released into foreign ecosystems at the ship's destination. This form of unintentional transportation has been a significant factor in the spread of invasive species across different marine regions, causing environmental and economic concerns [19].

In their new habitats, invasive species can threaten local ecosystems and biodiversity through competition with native species, predation, environmental alteration, and disease transmission. These intruders can also impose economic costs, affecting industries such as agriculture, forestry, and fisheries. They may alter soil chemistry, disrupt nutrient cycles, or modify water flow patterns, as well as lead to disease transmission, all of which can negatively affect native species and ecosystems.

The complexities of invasive species and their transport mechanisms, particularly through human activities like shipping, require an in-depth understanding to devise effective prevention and management strategies. As globalization increases, so does the risk of invasions, making the issue ever more pressing.

When non-native species outcompete local organisms for resources, the native species may decline or even face extinction. The alteration of local food web dynamics through predation by invasive species can further lead to imbalances in the ecosystem. Even changes in soil chemistry or water flow patterns can create conditions that favor the invasive species, amplifying their impact.

The economic consequences of these invasions are also noteworthy, as they can lead to decreased crop yields or increased costs in managing forests and fisheries. A 2017 meta-analysis sought to discern the specific ecological factors that mediate the impact of invasive species on biodiversity loss, including elements like trophic position, taxonomic groups, habitat type, and listing as harmful invaders.

The study analyzed 185 research papers, comprising 253 numerical values of species richness changes due to invasions. Results indicated that plant invaders, especially from the Poaceae family, were predominant. Animal predation was found to correlate with the largest decrease in species richness—21% in aquatic and 27% in terrestrial habitats, with birds experiencing the most significant decline at 41%. Furthermore, the findings suggest that in Europe, declines in species richness are spatially interconnected. This emphasizes that the implications of invasive species go beyond local-scale analysis, and that a broader perspective is essential for understanding and effectively mitigating these threats [20].

Urbanization

Urbanization is a key driver of biodiversity loss, causing an array of adverse effects on ecosystems. A paper by Grimm et al. [21] provides an overview of the impacts of urbanization on biodiversity and the environment, including habitat fragmentation, introduction of non-native species, and pollution. Urbanization involves the conversion of natural landscapes, such as forests, wetlands, and grasslands, into built environments for human habitation and activities. This process invariably leads to the destruction and fragmentation of natural habitats.

Habitat destruction eliminates the homes of various species, often causing their populations to dwindle or vanish entirely. Fragmentation, on the other hand, splits larger habitats into smaller, isolated patches.

Isolation can hinder species' mobility, limit their access to resources, and disrupt breeding, which can reduce genetic diversity and increase the likelihood of local extinctions, all contributing to a decrease in biodiversity.

Urbanization and Pollution of Local Ecosystems

Urbanization can also result in pollution, such as air and water pollution, which can have negative impacts on species and ecosystems. Air pollution can cause respiratory problems for wildlife, acidify soil and water bodies, and lead to the formation of harmful ground-level ozone, all of which can disrupt plant growth and animal habitats. Additionally, air pollution can contribute to climate change, which is a major threat to biodiversity. Water pollution can result in the degradation of aquatic habitats, causing declines in populations of aquatic marine species. Toxic substances and excess nutrients can create dead zones and algal blooms, harming fish and invertebrates.

Urbanization can also lead to a reduction in green spaces and urbanization-related activities, such as traffic and construction, can disturb and fragment natural habitats. These disturbances can lead to the isolation of species, disrupt migratory patterns, and contribute to further loss of biodiversity [22-26].

Conclusions

The drivers of biodiversity loss are complex - this paper has examined the main drivers, namely land use change, climate change, overfishing, urbanization, and the introduction of invasive species. To avoid further biodiversity loss, the role of agricultural expansion and land use change becomes apparent as a cause of 85% of at-risk species.

Climate change is also a driver of biodiversity loss with its effects influencing nearly all ecosystems. Warming temperatures, ocean acidification, and high-impact events such as altered ocean currents could significantly disrupt ecosystems. This disruption poses survival threats causing biodiversity loss. Overfishing triggers cascading effects in the marine food chain, causing species extinction. Urbanization, characterized by urban development and expansion, results in the loss and fragmentation of natural habitats. This growth, coupled with growing levels of pollution and the introduction of non-native species, culminates biodiversity loss. Invasive species, introduced through human activities, pose an equally potent threat to biodiversity. By outcompeting native species, altering the environment, and spreading disease, invasive species can dramatically destabilize ecosystems.

There may be additional drivers, but these primary drivers of biodiversity loss underscore the need for globally coordinated efforts to mitigate the damage and safeguard the world's biodiversity.

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